SCIENCE

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BOTANY AS A NATIONAL ASSET[1]

IT seems timely to consider the relation of botany to national welfare, when all the sciences are being called upon to render such service as they can in the development of national resources, both material and intellectual. As botanists we realize the important points of contact between our science and human welfare, but the relation between the science of botany and these contacts is not generally appreciated. I am not concerned at present with our usefulness so much as with our reputation, which is in danger of limiting the development of both our science and our service. My attention has been called to this situation in two ways.

1. An increasing number of students of a practical turn of mind are being attracted to the physical sciences because such training is understood to connect definitely with practical activities of various kinds. These sciences are to be congratulated upon having established this connection in such a way that the general public can see it. This has not been accomplished by slighting the fundamentals, but by showing that the fundamentals must underlie all rational practise. Failure to establish this connection in the case of our science means that botany is in danger of being regarded by the general public, and by students who simply record public opinion, as the least practical of the sciences. This attitude is the result of various causes, but chief among them are the attitude of professional botanists, and the fact that the

[1] Address of the president of the Botanical Society of America, New York, December, 1916.

conspicuous practical aspects of botany have been segregated in such special institutions as schools of agriculture, quite distinct from the universities, where by implication only impractical botany is taught.

2. The recent organization of the National Research Council emphasizes the fact that botany must be recognized as a national asset to be developed. The purpose of this council is to bring into cooperation all of those scientific and practical activities which have to do with national welfare. It is an attempt to coordinate the intellectual resources of the country, so that they may be increased and may be available. Since the organization of this council, I have been asked what a botanist has to do with national welfare. This is merely an expression of what seems to be a general feeling, that botany is not a science of human interest, an impression that botanists must correct. This does not mean a revolution in our work, which must deal with the fundamentals, but we must not allow these fundamentals to remain in cold isolation, entirely unrelated to the activities of life. This is not teaching a practise, but developing a vision. In my own experience, I have found that students, while working upon the purely scientific aspects of plants, respond with what seems like gratified surprise to suggestions that all this underlies the possibility of a much more effective handling of plants in supplying human needs.

I wish now to analyze the situation, that we may have it before us clearly; and at the same time to outline the perspective that may change it, and rehabilitate botany in public estimation as the most important of all sciences to human welfare. In fact, I am asking cooperation in arousing the public to a realization of the fact that botany may be made one of the greatest assets of a nation.

We should realize first how the present condition of scholarly isolation has arisen. Men who spend their lives in universities, especially the older ones, are apt to develop certain unfortunate peculiarities. These peculiarities may not make them less happy or less useful to their professional students, but they diminish the appreciation of the community at large. There is a peculiar kind of isolation that is bound to react. It is partly the isolation of a subject which seems more or less remote from general human interests, at least in the aspects the university investigator is cultivating. As a consequence, he feels that his world is quite apart from that one in which the majority of men are living. He is conscious of an interest distinct from their interests, which seem to him therefore relatively trivial. This sense of intellectual aloofness does not result in a feeling of loneliness, but rather in a feeling of superiority; unconscious in many cases, but often naïvely expressed.

It is also the isolation of authority, which comes from the mastery of a subject and association with students who recognize this mastery. To speak with authority in a subject, to give the deciding word, to meet a constant succession of inferiors, is apt to affect any man's outlook on the world of practical affairs. Either he becomes dogmatic in expression, or he must hold himself in check with an effort.

As a consequence, men engaged in fundamental botanical research are apt to be looked upon in general as inoffensive, but rather curious and useless members of the social order. If an investigator touches now and then upon something that the public regards as useful, he is singled out as a glaring exception. If an investigation lends itself to announcement in exceedingly sensational form, as if it were uncovering deep mysteries, the investigator becomes a

marked man, and in all probability he is called a "wizard." The fact is that the great body of investigators, who are doing the substantial work that makes for scientific and practical progress, are unknown to the public. My thesis is that what may be called the pure science of botany should be recognized as underlying all the effective practical handling of plants.

For fear of being misunderstood, I wish to define briefly what I regard as the most important ideal of botany, as of all the sciences. It is to extend the boundaries of knowledge, the goal being to understand nature. This ideal includes no thought of making nature a servant to minister to our needs. To know nature simply because it is wonderful and worth knowing is what it means. Such investigation is like the exploration of an unknown continent. Every advance into the new territory impresses us with the fact that it is far more extensive than we had dreamed. Every trail is worth following because it means additional knowledge. Some trails may lead to rich farm lands and gold mines, but in exploration these are only incidents. To understand the new country, all trails must be followed and mapped.

What may be called practical botany is beginning to realize the importance of exploration. This is indicated perhaps most significantly by the change of attitude in the scientific work of the government. The Bureau of Plant Industry, for example, during the last few years has been adding notably to its staff of scientific explorers. The reason for this has been a realization of the fact that practical application is sterile unless there is a continuous discovery of something to apply.

That scientific exploration is entering upon an advanced stage of its development is shown by the fact that it is proceeding in its method from analysis to synthesis. Until recently progress in botany was marked by an increasing segregation of subjects, so that botanists were distributed into numerous pigeon holes and labeled. A man in one pigeon hole knew little of the work of his colleagues, and cared less. This segregation was immensely useful in the development of the technique of botany; but now we realize the fact that nature is not pigeon-holed, but is a great synthesis; and we know that to understand plants, which is to synthesize our results, all of our so-called sciences must focus upon the problems. We have discovered that to know plants and their relations to the synthesis we call nature, we must know not only their structure and habits, but also the chemistry of the materials that affect their living, the physics of the variable conditions that they must face, the geological record of their changes; in short, botany has become the focusing of all the sciences upon the problems of plants.

In one sense scientific exploration is a luxury, just as music or art or literature, and must be recognized as a response to a high human impulse, the impulse to *know;* but we must correct the impression that botanical exploration is merely a luxury. We have been minimizing our opportunities for botanical research by allowing the impression to continue that our results hold no relation to human welfare.

This impression has been developed chiefly by the fact that two aspects of science are generally recognized, known as "pure" and "applied." There is little general appreciation of the vital connection between these two phases of botany. Not only does the distinction exist in the public mind, but it is reinforced also by published statements from colleges and universities. The distinction seems to be that pure science is of no material service to mankind; and that applied science

ministers to our material needs. The distinction, therefore, is based upon material output. In other words, pure science only *knows* things, while applied science knows how *to do* things. Since the modern American community believes chiefly in doing things, pure science seems to it useless, and the reaction of this sentiment upon opportunities for the cultivation of pure science is obvious.

I must confess that this feeling is too often intensified by those of us who are university investigators. We believe in knowing things, quite apart from their usefulness; and therefore we are in danger of regarding applied science as a waste of investigative energy, and its devotees appear to be unscientific; very useful, but not to be recognized as belonging to the scientific cult, the cult of explorers.

I wish now to outline a campaign of education which should lead to a general appreciation of the fact that botanical exploration can be made our most important national asset. The relation between pure and applied botany can be presented in a series of illustrations by outlining the usual steps that have been taken in the material service of botany to mankind.

In one case an investigator is attracted by a problem. No thought of its usefulness in a material way is in his mind; he wishes simply to make a contribution to knowledge. He succeeds in solving his problem and is satisfied. Later, perhaps many years later, some other scientific man discovers that the results of the former may be used to revolutionize some empirical practise of agriculture. The application is made, but the public hears only of the second man, the one who made the practical application. Obviously, however, both men were of great material service. The ratio that exists between scientific men of the first type and those of the second is not known, but there is very great disparity.

In another case, an investigator is attracted by a problem whose solution may serve the community. He succeeds in solving it, perhaps makes his own application, and is satisfied. Later another scientific man discovers that the results of the former may be used to revolutionize certain fundamental conceptions of biological science. His statement is made and the scientific world recognizes only the second man, the pure scientist, but both men were of large scientific service.

It is evident that responsibility for the practical results of our science is to be shared by those engaged in pure science and those engaged in applied science. The only distinction, therefore, is not in the *result,* but in the *intent.* In fact, the difference between pure science and applied science in their practical aspects resolves itself into the difference between murder and manslaughter; it lies in the intention. In every end result of science that reaches the public there is an inextricable tangle of contributions. Between the source of energy and the point of application there may be much machinery, and perhaps none of it can be eliminated from the final estimate of values. And yet the public has been gazing at the practical electric light, and forgetting the unseen and therefore apparently impractical power house.

All science is one. Pure science is often immensely practical, applied science is often very pure science, and between the two there is no dividing line. They are like the end members of a long and intergrading series; very distinct in their isolated and extreme expression, but completely connected. If distinction must be expressed in terms where no sharp distinction exists, it may be expressed by the terms "fundamental" and "superficial." They are terms of comparison and admit of every intergrade. In general, a university devoted to research should be interested in

the fundamental things, the larger truths that increase the general perspective of knowledge, and may underlie the possibilities of material progress in many directions. On the other hand, the immediate material needs of the community are to be met by the superficial things of science, the external touch of the more fundamental things. The series may move in either direction, but its end members must always hold the same relative positions. The first stimulus may be our need, and a superficial science meets it, but in so doing it may put us on the trail that leads to the fundamental things of science. On the other hand, the fundamentals may be gripped first, and only later find some superficial expression. The series is often attacked first in some intermediate region, and probably most of the research in pure science may be so placed; that is, it is relatively fundamental, but it is also relatively superficial. The real progress of science is away from the superficial toward the fundamental; and the more fundamental are the results, the more extensive may be their superficial expression.

In our campaign of education, which is to develop some appreciation of the fact that botanical exploration is a great national asset, concrete illustrations must be used to show that what people regard as applied science, which seems to them therefore useful and worthy of support, is but a superficial expression of fundamental things which it is the mission of pure science to discover. In other words, it must be known that the most practical science in the long run is the most fundamental.

I wish to illustrate my meaning by one concrete example, selected from many that will occur to any botanist. This will indicate how we can make the contacts between our pure science and the human welfare appreciated. The science of botany has had an interesting history. Beginning with the investigation of plants for what were called their "medicinal virtues," it developed with various progressions and retrogressions, until the botanist came to be regarded as about the most useless intelligent member of society. His chief concern seemed to remove him so far from the general human interest that he was regarded as a harmless crank at best, a man of only ephemeral interest. The most unfortunate result was that this public estimation of botany lingered much longer than it was deserved; and consequently, when the other sciences had won public esteem, either through their services or their appeal to the wonder instinct, botany lagged behind in public recognition, and in most educational institutions was the latest born in the family of sciences; but finally it also began to render signal service and appeal to the wonder instinct.

Among the several phases of botanical activity, phases which deal with the fundamentals of plant activity of all kinds, and are directly related to plant production, I wish to select plant breeding as a single illustration. It is not my purpose to recite the notable achievements that can be grouped under this title, for they are familiar to all of you. I wish simply to use plant breeding as a brief and concrete illustration of my thesis.

The *practical* aspect of plant breeding in a certain sense is as old as the cultivation of plants. Long experience in the practical handling of plants developed a kind of knowledge that became formulated in empirical practise; that is, practise whose meaning was not understood, but whose result experience assured. In general, the improvement of old forms by continuous selection grew into a fairly successful empirical practise.

During all this period of plant improve-

ment by selection, the so-called science of botany was cultivating a singularly distant field. In short, botany was not practical, and plant breeding was not scientific. As a consequence, botanists, on the one hand, and agriculturists, horticulturists, etc., on the other hand, were as distinct from one another as if they had nothing in common. It so happened that botanists were dealing with superficial problems in a scientific way, and plant breeders were dealing with the most fundamental problems in an empirical way.

As in any practise, plant breeding developed now and then an unusually successful practitioner, who made distinct contributions in the form of important results; but this represented no more of a real advance than does the fact that one cook can surpass another cook in the art of making bread.

What may be called the second period of plant breeding was ushered in when organic evolution began to be put upon an experimental basis. Plant breeding had been practical, but with no scientific basis; now a new plant breeding was established which was scientific, but with no practical motive. The new motive was the accumulation of data bearing upon the problem of inheritance. As a by-product of this work on inheritance, some of the scientific results have been applied to practical plant breeding, and the result has been an expansion of its possibilities that may well be called marvelous. In short, practical plant breeding is now on a scientific basis, and botany has at last attacked the fundamental problems and is beginning to be of great practical service.

In presenting this fleeting glimpse of the problems and accomplishments of plant breeding, I have attempted to emphasize the inextricable entanglement of pure and applied science. Any result of scientific plant breeding, representing as it must additional knowledge of the processes of inheritance, may become of practical service; and any result of practical plant breeding, involving as it does extensive experiments with plants, may prove to be of great scientific value. They are mutually stimulating, and both are necessary to the most rapid development of knowledge. This suggests that the botanical perspective to be developed in our campaign of education might be stated as practise based on science, and science that illuminates and extends practise.

In connection with the organization of the National Research Council, I feel that American botany is offered a great opportunity of which we should take advantage. As a member of the council I wish to acquaint you with its purpose, so far as botany is concerned. Since the organization of the council was stimulated by the desire to develop a program of national preparedness, the natural first impression would be that, so far as botany is concerned, it is merely the problem of more efficient food production and distribution. This would stamp the enterprise at once as a problem of practical agriculture, in connection with which botanical investigators who are dealing with the fundamental problems of plants would have little or no part. Nothing is further from the intention of the council. The chairman has recently outlined the work of the council briefly as follows:

1. To prepare a national census of research, showing what laboratories and investigators are available.

2. To encourage the cooperation of educational and research institutions in working out problems of pure science and industry.

3. To promote research in various branches of science in cooperation with leading national scientific societies.

4. To encourage scientific research in educational institutions. It is proposed, for instance,

that in each advanced educational institution there be a committee on research to promote original investigations on the part of the faculty and graduate students.

5. To establish research fellowships in educational institutions, thus affording qualified workers an opportunity to devote themselves entirely to research work.

6. To secure wherever possible endowments for research purposes.

It is evident that so far from being primarily work in the practical application of what we know already, the enterprise is intended to be primarily a stimulus to fundamental research in every direction. It is not *practical application* that is to be stimulated chiefly, but *exploration,* which may or may not result in practical application. It is felt, for example, that the more we know about the structures and activities of plants, the better equipped we shall be to handle plants intelligently. Our botanical program, therefore, is simply to extend the boundaries of our knowledge of plants as far as possible. In pursuance of this program, at least two things are felt to be necessary.

In the first place, there must be developed some scheme of cooperation among our botanical establishments; and notably between the research establishments and the so-called practical establishments. For example, we recognize in general three great botanical agencies at work to-day, working independently, and in too great ignorance of each other's results. These agencies are the Department of Agriculture, the agricultural colleges and experiment stations, and the universities. All of these agencies are investigating plants from various points of view, but they are not as mutually helpful, or even as mutually stimulating as they should be in the interest of progress. I have met many cases of men intellectually equipped to work, but with no adequate material or equipment; and also even more cases of fine equipment and abundant material, and no man trained to use them effectively. In other words, the distribution of men and equipment is not as effective as it should be.

In the second place, there must be developed some plan of supporting research wherever there is a competent investigator. The movement to establish research fellowships has begun already, and as the value of research becomes better understood, there is no reason to doubt that every botanical explorer will have the opportunity to explore. There is at present a tremendous amount of waste in the investigators produced by the universities. Every year scores of young investigators, well equipped to continue exploration, are automatically side-tracked by a degree, and forced into positions where investigation is killed, or at least becomes anemic. The council proposes to conserve some of this investigative ability, and to give it a chance to express itself. In short, the opportunity now presented to us is to increase the opportunities for botanical research to such an extent by cooperation and conservation of investigative ability that the progress of botany should take on a greatly increased momentum. And all this can be done if at this psychological moment we as botanists can make it clear that a fundamental knowledge of plants is a great national asset.

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THE COMMITTEE OF ONE HUNDRED ON SCIENTIFIC RESEARCH OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

REPORT OF THE SUBCOMMITTEE ON ENGINEERING

IN view of the fact that a subcommittee on engineering has only very recently been appointed by the American Association for the Advancement of Science committee of one